

## PLEISTOCENE DEPOSITS AND FOSSIL VERTEBRATES FROM THE "DEAD HEART OF AUSTRALIA"

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Tedford, R.H. and Wells, R.T. 1990 3 31: Pleistocene Deposits and Fossil Vertebrates from the "Dead Heart of Australia". *Mem. Qd Mus.*, 28(1): 263-284. Brisbane. ISSN 0079-8835.

The first vertebrate fossils from central Australia were found in Quaternary deposits in the eastern Lake Eyre Basin, South Australia, at the end of the last century. Substantial collections were made by the J.W. Gregory expedition early this century. Further collecting and geologic observations along with the earlier collections permit reconstruction of this area's history for the latter part of the Pleistocene. Two major periods of sediment accumulation are recognized. The older (Kutjitara Formation) is associated with the penultimate glacial period, and the younger (Katipiri Formation) with the last glacial period. The Kutjitara Formation comprises fluvial deposits derived locally from distributary stream systems ("prior streams") that drained the hinterlands of pre-Quaternary rocks surrounding the Lake Eyre Basin. Interbedded within this sequence are salt-lake sediments and groundwater deposits of gypsum indicative of dry periods, though there is no evidence of dune development. The Katipiri Formation is also largely of fluvial nature but represents a more integrated drainage system similar to that existing today. The Katipiri sediments are the "ancestral" rivers of the Cooper and Warburton drainages. These rivers were very sinuous, similar to their present-day descendants, and preserve a record of decreasing discharge. They also drained into the Lake Eyre salina. The aeolian facies of the Katipiri Formation is represented by transverse and longitudinal dunes derived from river sediments and formed in the arid phase associated with the last glacial maximum. The reorganization of the drainage system from Kutjitara to Katipiri times is related to tectonic subsidence.

Fossil vertebrates were recovered from both the Kutjitara and Katipiri Formations. The last appearance of many forms, particularly the large species, is associated with the hyper-arid environments of the last glacial maximum. "Disharmonious" vertebrate faunas of extant taxa are recorded in central Australia as well as around the margins of the continent during the last glacial. The geographic dispersal of their components is indicative of habitat changes affecting the centre of the continent.

□ *Pleistocene, Marsupialia, Aves, Reptilia, Pisces, Geomorphology.*

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South Australia State Geologist H.Y.L. Brown discovered Pleistocene vertebrates in central Australia in 1892. His collection was obtained on the Warburton River "between Toopawarrina waterhole and Kalamurina station", and included fossil "reptilian teeth; scales, and bones, apparently of crocodiles and turtles; teeth of diprotodon-one upper jaw, having all the teeth (five in number) in a good state of preservation-bones of the diprotodon, the largest of which is a thigh-bone, 15 inches in circumference, and bones and teeth of smaller marsupials, kangaroos etc". These remains were submitted to R. Etheridge, Jr, then Palaeontologist of the Geological Survey of New South Wales, who confirmed (1894) the presence of *Diprotodon* (represented by a left maxillary fragment with

P/3M2-5). This, along with the other marsupial and some reptilian remains, was presented to the South Australian Museum in 1899 but not further described. Etheridge (1894), in consultation with C.W. de Vis, Curator of the Queensland Museum, described and figured a thoracic and a lumbar vertebra of the giant varanid lizard *Megalania*, crocodilian scutes and coprolites identified by de Vis as "an alligator", *Pallimnarchus pollens*, turtle shell fragments (Chelidae in Gaffney, 1981, p. 16), and the distal end of a right tarsometatarsus of a pelican — which de Vis described as *Pelicanus validipes* n. sp. (De Vis in Etheridge, 1894, p. 21, pl. 2, fig. 5, 6; later referred to the living *P. conspicillatus* by Rich & Van Tets, 1981). Brown (1892, p. 5) gave three sections showing the stratigraphy at the fossil sites and commented that,

although the specimens had been found in the bed of the Warburton River, "they appear to have been washed out of the sand and clay banks by the floods, although . . . none [were observed] *in situ* in these banks".

These reports, and those of Debney (1881a, b) and Tate (1886), concerning fossils from the lower Cooper Creek, stimulated J.W. Gregory, Professor of Geology, Melbourne University, and Director of the Geological Survey Branch of the Mines Department of Victoria, to make a more comprehensive search for vertebrate fossils east of Lake Eyre in South Australia. Gregory (1906, p. 145) explained in a statement that remains a succinct rationale for all the subsequent palaeontological work in the area, that "the objects of the expedition to Lake Eyre were to secure a collection of the fossils of that area, to determine with greater precision the age of the giant marsupials that once lived there, to gain further information as to the geological history of Central Australia; and to see what light geology could throw on the legends and original home of the aborigines". Accordingly, in December 1901 and January 1902, Gregory, his assistant H.J. Grayson, and five Melbourne University students explored the lower reaches of Cooper Creek and the Warburton River, east of Lake Eyre, South Australia, and secured a collection of fossil vertebrates from these water-courses in the same manner as H.Y.L. Brown. This heroic trip, conducted without serious incident in mid-summer heat and near the peak of the devastating

turn-of-century drought, was described in Gregory's famous work "The Dead Heart of Australia" (1906), the title contributing to the vernacular of Australia. The collections obtained by Gregory's pioneer party were never fully described beyond de Vis' (1905) account of the smaller birds which became part of the Queensland Museum collection (see Rich & Van Tets, 1982, Table 5 for summary). The remaining fossil vertebrates were deposited in the Hunterian Museum of Glasgow University by Gregory on his return to Scotland in 1905. These collections were studied by W.E. Swinton in the early 1920s (unpublished report, Hunterian Museum). Except for White's (1925) description of the lungfish remains, the Gregory collection received no further notice in the literature.

Fifty years later, R.A. Stirton and R.H. Tedford, then at the University of California, inspired by Gregory's narrative, retraced his journey, collected further fossils and studied the stratigraphy associated with them. Their work (with palaeornithologist Alden Miller), summarized in 1961, gave the first faunal list for the collections obtained on Cooper Creek. Gregory, like Brown, did not find material *in situ* and made no detailed studies of the stratigraphy exposed in the banks of the Cooper and Warburton. Stirton, Tedford and Miller (1961) determined the local stratigraphic sequence and found sufficient material *in situ* to identify the source of the fossils.

TABLE 1. Equivalent Nomenclature for Fossil Localities, Cooper Creek.

Swinton ms	J.W. Gregory 1906	Reuter 1901 ms	Lands Dpt. S. Aust
Hunterian Museum	Text (T), Map (M)	Map	Pastoral Maps
Lower Cooper Locality 1	Eli Hartig's Soak (T:85) Unduwumpa (T:84) Unduwumpa (M) Patara Mordu (T:84) Pataramordu (M)	Wunduwompana	
Lower Cooper Locality 2			
Lower Cooper Locality 3			
Lower Cooper Locality 4			
Lower Cooper Locality 5			
Undusoumpa			
Lower Cooper Locality 6	Kuttipirra (T:84) Kutupirra (M)	Katipiri	Cuttupirra
Lower Cooper Locality 7			
Emu Camp			
Pearam (East of)	Emu Camp (T:80, M)	Malkuni	Malcoona (1897) Malgoona (1974)
	Markoni (T:80, M)		
	Malkuni (T:80)	Pijari	Pirranna Soak
	Piaranni (T:78)		
	Piranni (M)	Parlangunku	White Crossing
	Palankarinna (T:78)		

In subsequent years additional study of the youngest deposits in the Lake Eyre Basin has been undertaken while working on the Tertiary rocks, and in 1980 and 1983 a special study by the authors and their colleagues amplified and greatly extended this early work. The purpose of this report is to provide further historical documentation of the Gregory expedition so that their collections can be localized, and thus incorporated in a synthesis of the Stirton data with results of our more recent research.

ABBREVIATIONS: FUAM, field catalogue of Flinders University-American Museum of Natural History collections 1980, 1983 ultimately to be catalogued in the South Australian Museum collection; HM, Hunterian Museum, Glasgow University; LDSA, Lands Department, South Australia; QM, Queensland Museum; SAM, South Australian Museum; UCMP, University of California, Museum of Paleontology. Serial identification of marsupial cheek teeth follows Archer (1978). Ka, indicates dates in thousands of years ago; BP, before present; Coll, collections.

## THE GREGORY EXPEDITION, 1901-2

Documentation of the itinerary of the Gregory party comes primarily from the narrative in the "Dead Heart of Australia" (Gregory, 1906, pp. 17-154, apparently reprinted from a series of letters submitted to the "Melbourne Age") and the accompanying map. The map is a generalization based on "pastoral plans of the Surveyor General of South Australia", and was modified along the routes of march, presumably from local observations. Native place-names on this map do not necessarily correspond with those in the text as to orthography; nor do they match phonetically similar forms used in the map accompanying the contemporary study of the Dieri people by J.G. Reuther (published in 1981). The various names for fossil sites are explained in Table 1. Gregory's fossil collections were documented only with place names and site numbers, using a system apparently adopted in the field. These names were used by de Vis (1905), and also by W.E. Swinton in his catalogue of the collection and his "Description of the vertebrate remains collected by Professor J.W. Gregory, D. Sc., FRS in the Lake Eyre district of South Australia", (ms, ca 1924). Despite wide enquiry we have not been able to find Gregory's journal of this expedition.

The narrative and map allow fairly accurate knowledge of the itinerary of the Gregory party,

especially the route along Cooper Creek, where camp sites can be located approximately on a modern planimetric base (Figs 1 and 2). Appendix I (by C.W. de Vis) in Gregory (1906) indicates that a system of numbering localities was adopted by the Gregory party for sites in the lower reaches of Cooper Creek. This system is also reflected in Swinton's catalogue; his manuscript reveals some correspondence between numbered sites that were also given names, e.g. Lower Cooper Locality 5 = Eli Hartig's Soak (Gregory 1906, p. 85; "Harty's" in Swinton ms., p. 11); Lower Cooper Locality 6 = Patara Mordu (Gregory 1906, p. 84; Swinton ms., p. 14). These sites occur in reverse numerical order downstream, indicating that the numbering proceeded upstream and that there are four sites further downstream. One of these must be the site mentioned in the text: "our collecting ground next morning was the richest we found during the expedition" (Gregory, 1906, p. 93). This site can be located because of the full description of the previous day's march from Camp 5 (Fig. 2), and from the fact that this site, Lower Cooper Locality 4, produced more specimens (93) than any other locality. The remaining three localities were further downstream; each was a sand bar in the channel, most likely just downstream from prominent outcrops of Quaternary deposits cut by the river in flood. Their approximate locations are shown in Fig. 2. Other Cooper Creek localities can be matched to place names on the maps consulted. The most important site for the Gregory party (and later workers) is near Emu Camp (227 catalogued specimens in the Gregory Coll.), which from the description includes the bars downstream from Malkuni Waterhole. Gregory's party did not camp at Emu Camp (in 1980 still marked by a yard of coolibah logs), but in the coolibahs at the eastern end of the "Markoni" Waterhole.

From Cooper Creek the Gregory party moved directly NNE in the interdune valleys to Kalamurina homestead (then, as now, deserted) on the Warburton (called "Diamantina" by Gregory). Leaving most of the party at Kalamurina to collect in the vicinity of the homestead, Gregory, Grayson, a guide and another assistant travelled up the Warburton to the stony crossing at Ulabarinna (Oolabarrina of LDSA, Pastoral Plan 16S, 1897), one of the sites from which the Brown Coll. had been obtained (Fig. 1). Only 23 specimens were obtained from this site, where Quaternary deposits overlie a silcrete developed on Tertiary rocks. A larger collection (159 specimens) was obtained by the main party in the vicinity of Kalamurina. Specimens were probably obtained beneath

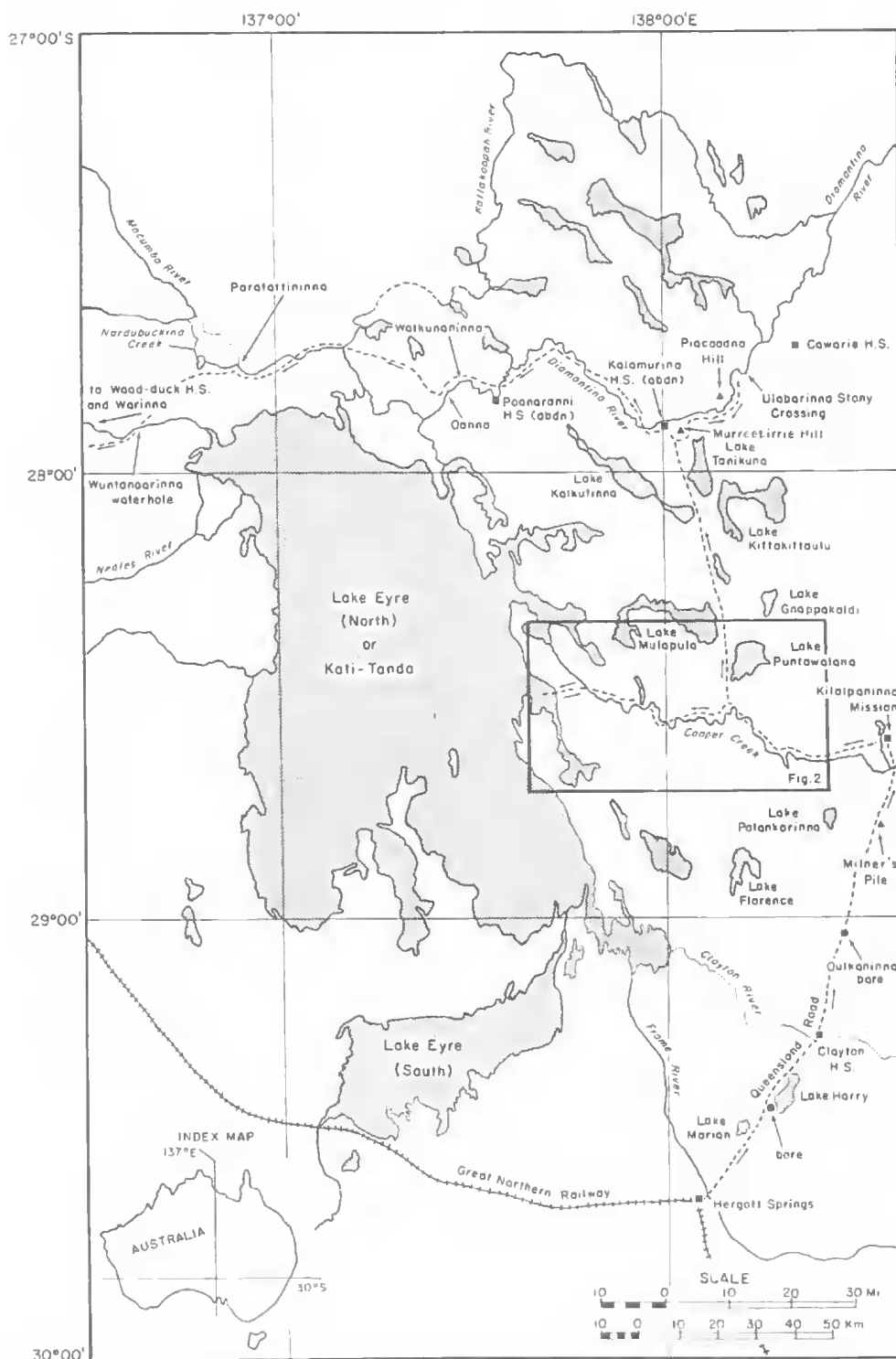


FIG. 1. Index map of part northeastern South Australia showing the position of Figure 2. The 1906 Gregory Expedition (route) and landmarks are given their contemporary orthography.

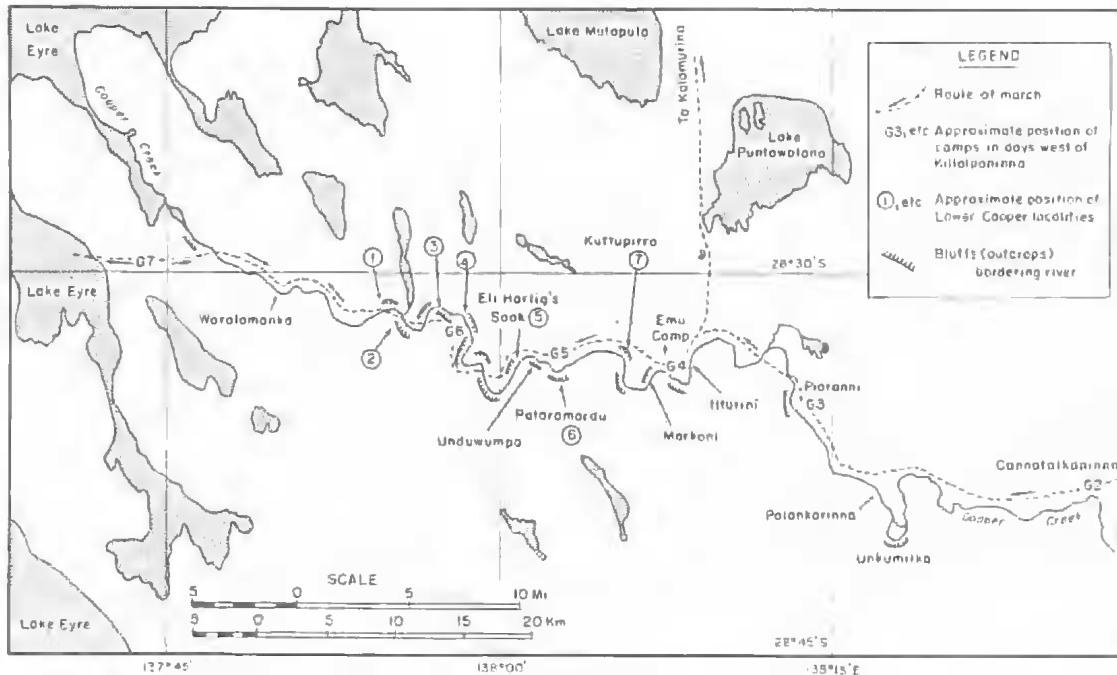


FIG. 2. Map of the lower Cooper Creek showing details of route and camps of the Gregory Expedition (deduced from Gregory 1906), and the approximate position of his localities (see Table 1).

prominent outcrops on the north bank of the river from just north of the homestead downstream nearly to Toolapinna Soak. Part of Brown's Coll. was also obtained near Kalamurina. Two views of outcrops at the western end of this stretch of river are shown by Gregory (1906, photographs opposite pp. 110 and 116) and can be identified as the "Lookout Locality", UCMP locality V5756 (Fig. 4), of the Stirton party. Realizing that only ten days remained to get from Kalamurina to the railway at Warinna, W of Lake Eyre, the Gregory party set off on a direct march. Gregory noted the occurrences of *Diprotodon* bones high in the bluff just N of Poonaranni (1906, p. 125) and at river level nearer Ouana (ibid., p. 126) on the W side of the river below Poonaranni (Poonarunna of the LDSA Pastoral Plan 16S, 1897). The HM catalogue records sites as "Poonaranni", "near Poonaranni", "E. of Poonaranni", "SW Poonaranni", a total of 13 specimens collected while the party was camped at this abandoned "horse-station" (Gregory 1906, p. 122).

The Cooper and Warburton sites mentioned above can be located closely, and most have been visited in subsequent work. Present stratigraphic knowledge allows the placement of the fossil remains in geological context. There are two Gregory sites that yielded important collections,

particularly bird remains described by de Vis (1905), but the position of which, even relative to the major drainages, is uncertain: "Wurdulumankula" produced 26 (HM), and 15 (QM) bird specimens. There is no similar place-name on Gregory's (1906) map, but the Reuter map (ms. 1901) has a phonetically related "Mudlamarukupa" on the Cooper at the approximate location of Gregory's "Lower Cooper Locality 2", the second most prolific site on the lower Cooper (81 specimens). A second possibility is "Warremandoona" Waterhole (LDSA Pastoral Plan 16S, 1879; "Warimardu" of Reuter ms., 1901), a little north of "Itturini" ("Itturinna" waterhole of the LDSA Pastoral Plan 16S, 1879) where the Gregory party left the Cooper to cross the Tirari Desert to Kalamurina. The second site is "Wankamamina" (with "Wankamurina" as a synonym, Swinton ms., p. 9) which produced 26 (HM) specimens, and two (QM) birds. The related "Waikunaninna" is shown on Gregory's (1906) map downstream from Poonarunna at about the point he referred to on pp. 125-126, but the party was moving rapidly at this time. It seems more likely that a collection of this size would originate from one of the sites between Kalamurina and Ulabarinna where the site "Wadlakanninna" (Gregory, 1906, p. 112) or

"Wadlarkaninna" Waterhole of the 1897 LDSA Pastoral Plan 16S seems phonetically related ("Wadlajerkina" Reuter ms. 1901, map).

### SUBSEQUENT INVESTIGATIONS

Stirton (1954) described the initial attempt in 1953 to reinvestigate the Gregory sites; a narrative of the Stirton expeditions E of Lake Eyre to 1963 is given by Tedford (1985). By the early 1960s those workers had retraced nearly the entire Gregory expedition route and obtained new collections from the same localities, some *in situ*, thus establishing provenance. At that time the Pleistocene fluvialite deposits were all grouped as a single stratigraphic unit, the Katipiri Sand; this was typified by cross-stratified, fine white sand that fills channels incised into red mudstones correlated with the Tirari Formation of Pliocene age at Katipiri Waterhole (Reuter ms. 1901, map orthography; Cuttupirra of LDSA Pastoral Plan 16S, 1897 and later maps) on Cooper Creek (Fig. 2). All the channel-filling sands lying above the Tirari Formation and beneath the sandridges that dominate the modern topography were correlated with the Katipiri Sands. These were the deposits that produced most of the Gregory fossils and subsequent collections. Stirton, Tedford and Miller (1961) recognized that their collections included at least two different assemblages. The younger included abundant material from the Katipiri Sands at Malkuni Waterhole (also called "Markoni" by Gregory 1906, p. 80; "Malcoona" on LDSA Pastoral Plan 16S, 1897; and "Malgoona" on the recent Kooperamanna 1:250,000 sheet), the "Emu Camp" site of Gregory, about 1.6 km E of Katipiri. This assemblage, dominated by remains of *Diprotodon* and large kangaroos, was used to typify the Malkuni Fauna of Stirton *et al* (1961). A second, and presumed older fauna, in which *Diprotodon* was a very minor element (although confirmed to be present in later collections), was obtained from correlated Katipiri Sands at Lake Kanunka, 29 km NE of Malkuni Waterhole in the central Tirari Desert. The Kanunka Fauna includes a suite of macropodid genera similar to that of the Malkuni, but the species are different and more closely related to Pliocene taxa elsewhere. Subsequent work at Lake Kanunka has shown that the fossiliferous channel is a part of the Tirari Formation sequence.

Work conducted in 1980 and 1983 focused on the latest Cenozoic deposits. More comprehensive

stratigraphic studies were carried out, magnetostratigraphic investigations of the Tirari Formation were conducted, and further searches for fossils proved especially fruitful in the aftermath of the mid-century floods on the Cooper and Warburton. The remainder of this paper details some of the lithostratigraphic and biostratigraphic results of this work and, in combination with previously gathered facts, presents a synthesis of the geological history of the Quaternary deposits of the Tirari Desert E of Lake Eyre in South Australia.

### PLEISTOCENE DEPOSITS, TIRARI DESERT

The term Tirari Desert was first used by Gregory (1906, p. 100) for that region between the lower Cooper and Warburton roughly coinciding with Tirari tribal territory. Stirton *et al* (1961) expanded the term to include sandridge country from the Clayton River, SW of Lake Eyre North, to the Kallakoopah at the southern margin of the Simpson Desert. This region is bounded to the W by Lake Eyre North and to the E by the anticlinal uplifts that locally rim the late Cenozoic Lake Eyre Basin. The Cenozoic history of this region was summarized in Wells and Callen (1986), and the late Cenozoic deposits of the Tirari Desert have been discussed by Tedford, Wells and Williams (1986).

The regional depositional framework for the Pleistocene deposits is dramatically revealed by air photos, especially Landsat imagery, obtained during the 1980s flooded intervals in the Lake Eyre Basin (Tedford, Wells & Williams, 1986). Beneath the sandridges are preserved meander-belts of the ancestral Cooper Creek and Warburton River, partly followed by their entrenched present-day descendants (Fig. 3). The ancestral Cooper divided into two distributaries near present-day Unkumilka Waterhole, the southern branch extending southwestward beneath the Tirari dune field turning NW near Madigan Gulf of Lake Eyre North where a long inlet marks its probable course (Fig. 4). The northern branch took a westerly course leaving the present channel near Lake Kutjitarra and striking directly toward the opening of the same inlet of the lake into which the southern ancestral branch seems to head. The northern branch, followed by the present river, was deflected to its present course probably as a result of the development of the strandline dunes accompanying the recession of Lake Eyre in late



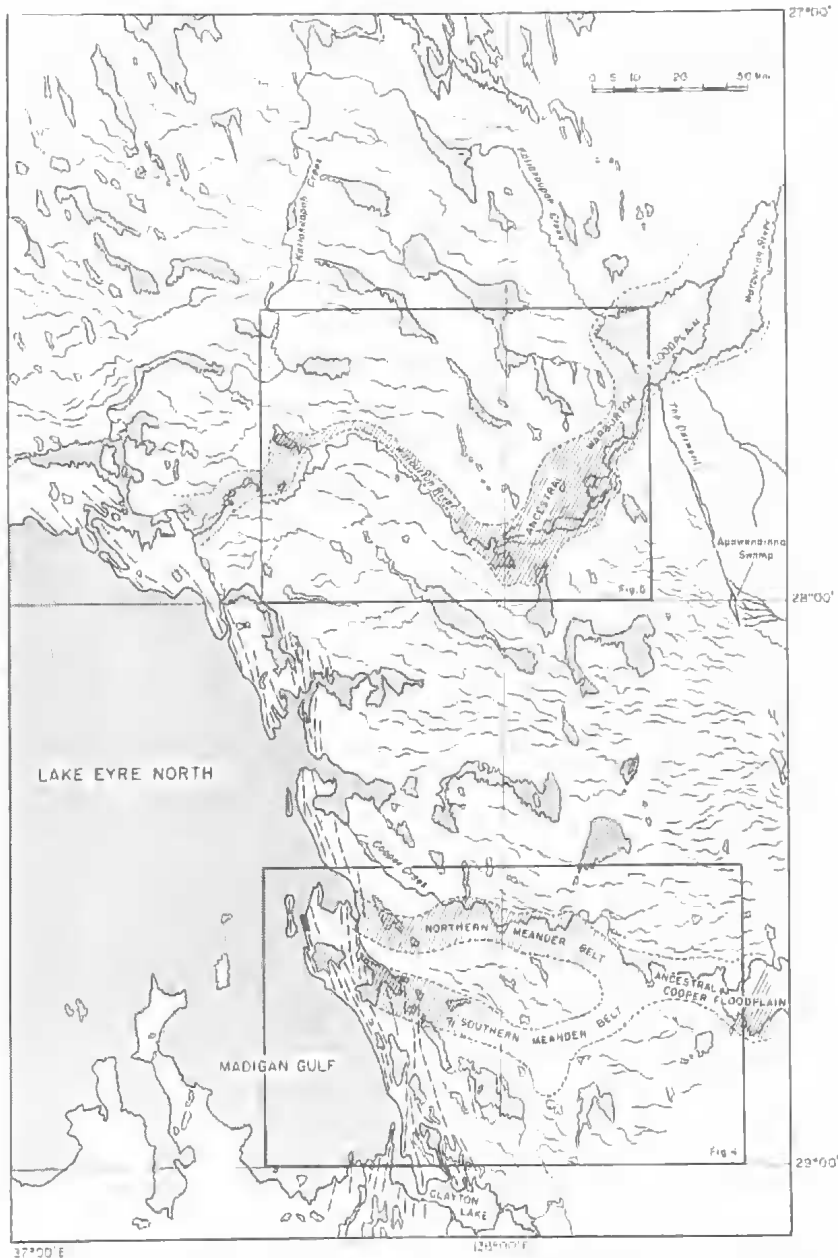


FIG. 3. Geomorphic map of Tirari Desert east and north of Lake Eyre in South Australia (traced from Landsat images 99-79, 80 and 98-80, January 1984, courtesy Bureau of Mineral Resources, Canberra). Position of Figs 4 and 5 shown. Prior streams of the Kutjitara Formation depositional system indicated by low sinuosity distributaries visible on 1984 Landsat images as chains of waterfilled pans. The salina prior-stream relationship in the northern part of the area, postulated by Krieg and Callen (1980), shown by the concordance in orientation of both features. The prior streams emanate from the flanks of pre-Quaternary uplifts just east of the map; and some can be traced to surviving drainage across these uplifts, such as at Apawandinna Swamp where such drainage is impounded on the edge of the last-glacial maximum Tirari dunefield and redirected into the Derwent, skirting the dunefield margin. Outlines of the meander belt of the ancestral Cooper and Warburton rivers are indicated. The narrow northwest limb of the lower Warburton is entrenched in late Tertiary rocks and probably occupies a prior stream valley in this part of its reach. Bold dashes indicate the trends of the gypcreted strandline dunefield of last glacial age along the eastern shore of Lake Eyre North (deduced from Landsat images and airphotos and checked by field observations in the Madigan Gulf region).

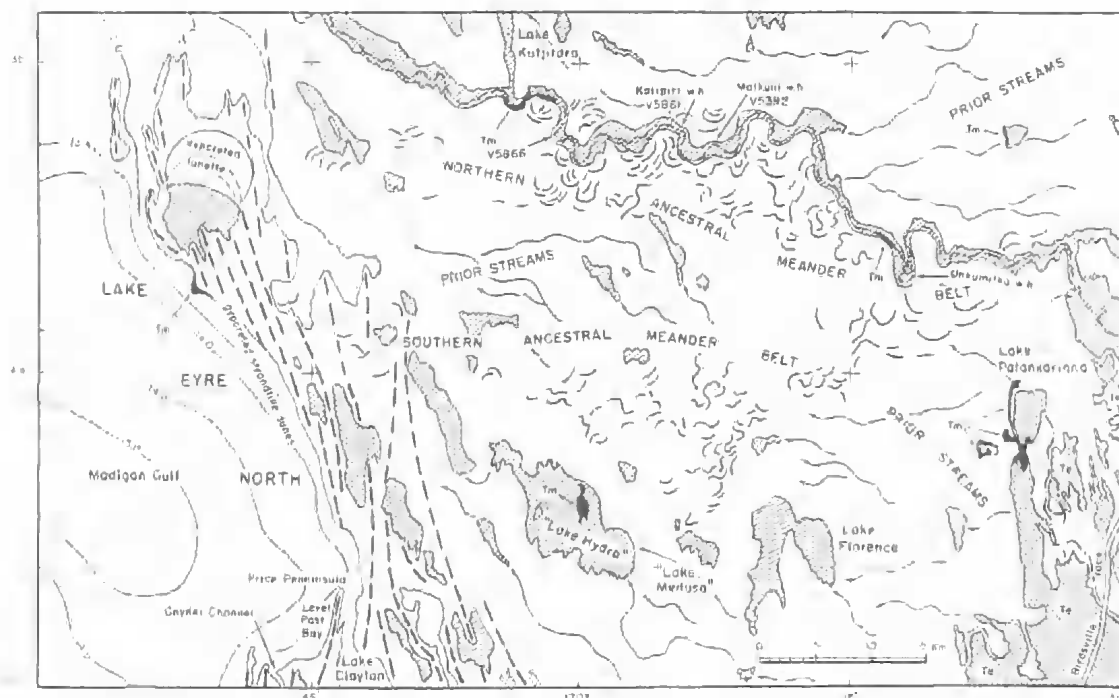


FIG. 4. Map of part of the lower Cooper Creek region (see Fig. 3). Salinas and modern floodplain — left oblique ruling; outcrops of Paleogene Eyre Formation (Te) — right oblique ruling; and medial Miocene Etadunna Formation (Tm) in black. Prior-stream channels visible on Landsat images shown with arrowed lines. Pointbars of two branches of the ancestral Cooper Creek visible on airphotos are also indicated. Trends of gypereted, last glacial, strandline dunes — bold dashes. Topography of Madigan Gulf floor in meters below sealevel shown. Numbers prefixed by "V" — UCMP localities; "w.h." — waterhole.

Pleistocene time. The shift in course of the southern branch may also be attributed to this recession.

The course of the ancestral Warburton is closely followed by the present river: both trend southwesterly to Kalamurina, where they turn abruptly NW following a trench cut in the Tirari Formation that forms bold outcrops on the western bank. At Keekalanna Soak the river again resumes a southwesterly course ultimately to the northern end of the Lake Eyre (Fig. 5).

These ancestral river tracts cross an earlier drainage field that consists of a low-sinuosity tributary system of westerly to northwesterly trend extending from the margins of the uplifted terrain forming the eastern rim of the Lake Eyre depositional basin (Figs 3, 4, 5). These prior streams and their floodplain represent a broad alluvial apron formed by local drainage, parts of which are preserved as elongate salinas or as chains of claypans which when waterfilled, as during episodes of present day flooding, indicate the courses and extent of this major geomorphic

element. The course of these prior streams gives no evidence of drainage having a catchment beyond the uplifted terrain in northeastern South Australia — indicating that the ancestral rivers represent the earliest evidence that Lake Eyre formed the focus of drainage comparable to that of the present-day. The prior streams trend W and NW, presumably focusing on a depocentre in the northern part of Lake Eyre North and NW of the lake in the southernmost Simpson Desert. Limited drilling there (Krieg & Callen, 1980) suggests a thick late Cenozoic section.

Outcrops exposed by entrenchment of the Cooper and Warburton, and those bordering the salinas within the Tirari Desert, illustrate the stratigraphic relationships of the two episodes of sedimentation indicated by geomorphology. The Kutjira Sands (Stirton, Tedford & Miller, 1961) are now recognized as part of the ancestral river deposits; the prior stream deposits are included in the Kutjira Formation discussed below. The stratigraphic relationship between the deposits,



developed from the Cooper Creek outcrops, will be discussed first, followed by consideration of correlative deposits on the Warburton.

#### COOPER CREEK

Favourable outcrops showing the Quaternary fluvial deposits beneath the Tirari dunefield occur at Katipiri Waterhole and downstream. Particularly instructive are those at Gregory's Lower Cooper Locality 4 where the friable and still active dunes rest on a plinth of older sandplain deposits indurated by a pedocal of calcareous nodules and rhizoconcretions, including carbonate casts of tree trunks (Fig. 6B). Such carbonate soils are widely distributed over the ancestral river deposits and correlative strandline facies near Lake Eyre. Fossil ratite eggshell associated with these deposits produce C14 dates near the limit of the radiocarbon method (Tedford, Wells & Williams,

1986, table 4). The deposits also yield remains of *Diprotodon*, *Macropus* cf. *M. titan*, wombat, and emu and *Genyornis* eggshell. These deposits pre-date the glacial maximum and offer a minimum date for the youngest fluvial deposits of the ancestral Cooper.

Beneath this calcreted sandsheet, the Katipiri Sands have a gypcrete caprock, not as well-developed near the present Cooper Creek as in adjacent terrain. This is the youngest of three gypsum-cemented caprocks that indurate the tops of the major depositional phases. They are related to saline groundwater levels that remained high in the basin during the waning phases of aggradation.

Entrenchment of the present Cooper Creek through the Katipiri Sands is first seen between Malkuni and Katipiri waterholes. At Malkuni the river floor exposes the basal Katipiri ancestral river deposits and their locally-rich accumulations of

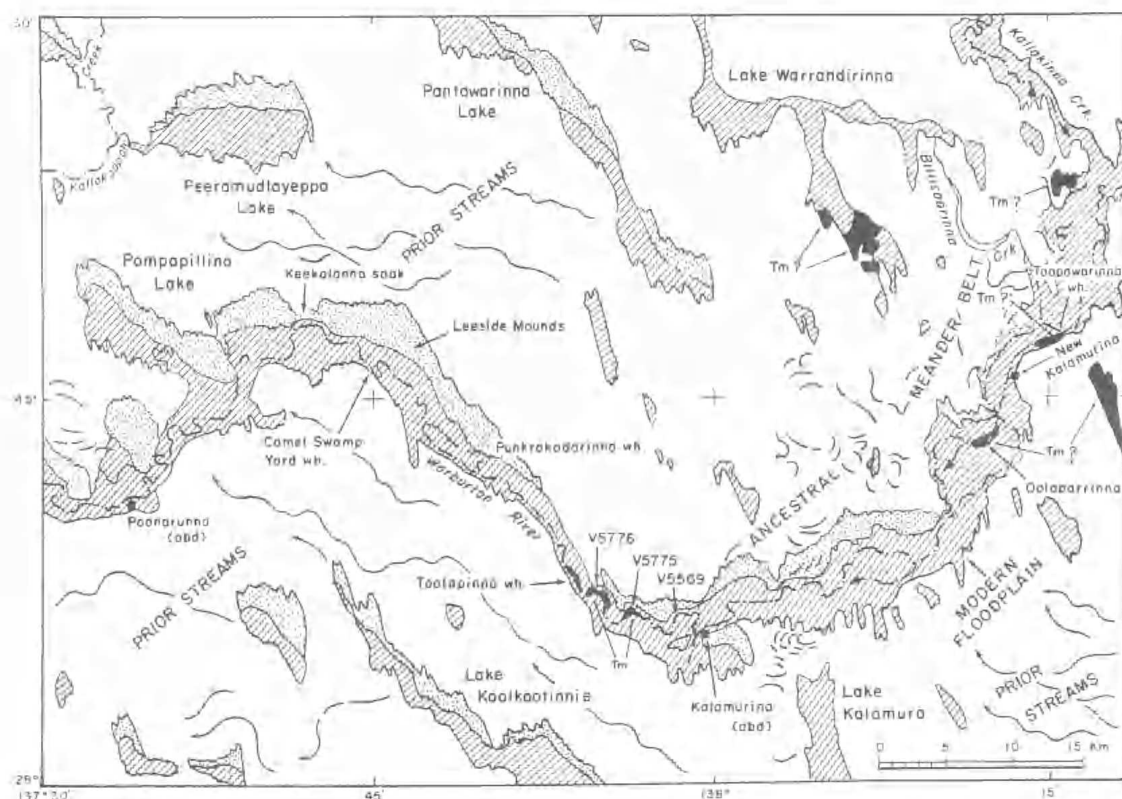


FIG. 5. Map of part of the lower Warburton River region (see Fig. 3), Salinas and modern floodplain — left oblique ruling. Silcreted younger Tertiary rocks questionably assigned to the Etadunna Formation (Tm?) and unsilicified claystones more typical of the Etadunna Formation (Tm) shown in black. Prior-stream courses visible on Landsat images — arrowed lines. Pointbars of an ancestral meander belt of the Warburton River plotted from air photos. Leaside mounds (stippled) playas and salinas taken from airphotos and Landsat imagery. Numbers prefixed by "V" — UCMP sites.

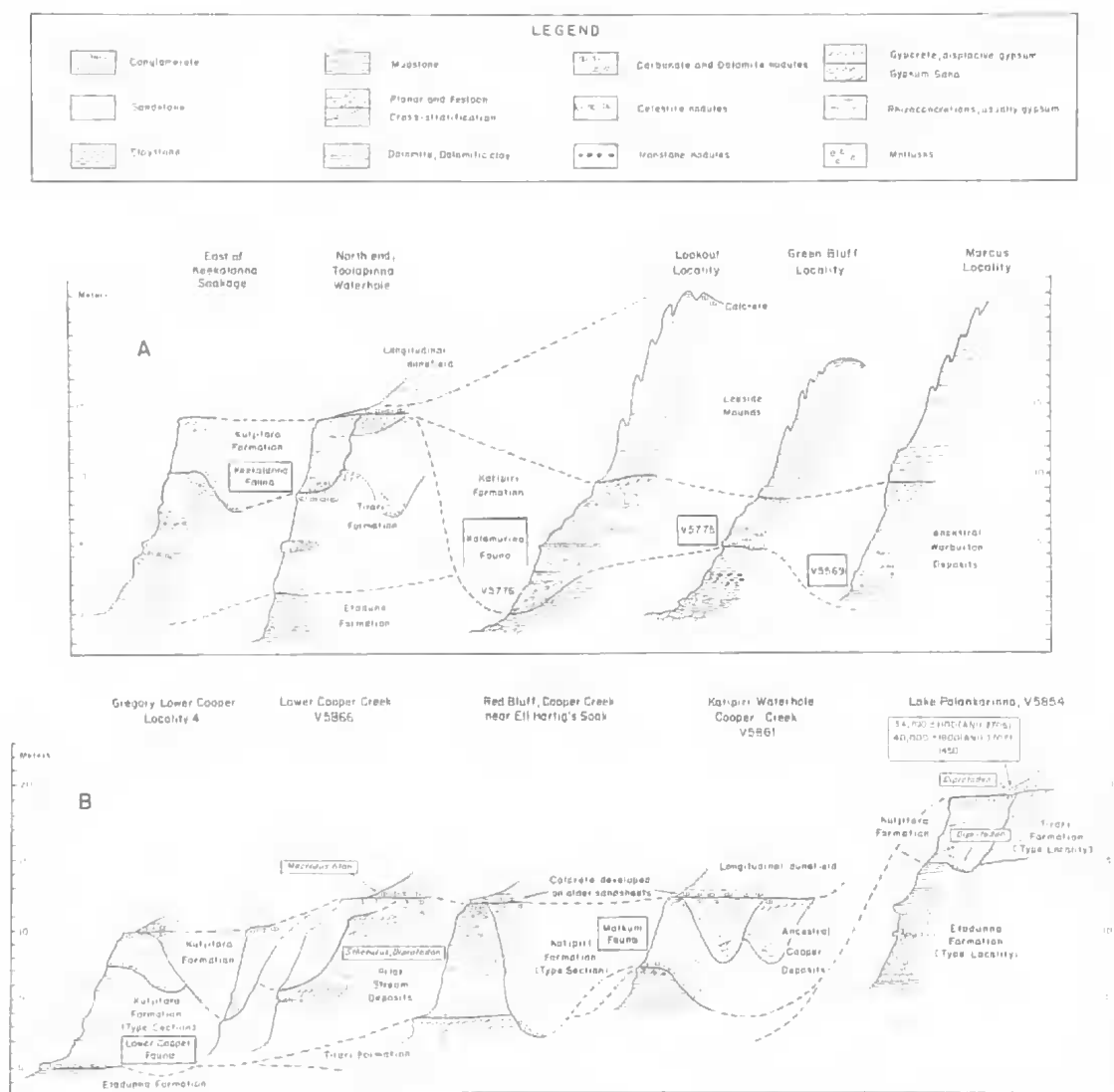


FIG. 6. A, columnar sections showing the relationships between exposed lithostratigraphic units along part of the lower reach of the Warburton River (see Fig. 5). Neogene strata assigned to the Miocene Etadunna and Plio-Pleistocene Tirari Formations form the substrate for the Quaternary Kutjira prior stream and floodplain and succeeding ancestral river deposits of the Katipiri Formation and capping aeolian sediments. Stratigraphic relationships of the penultimate glacial Keekalanna Fauna and last-glacial Kalamurina Fauna (UCMP sites V5776, V5775, V5569) shown by boxes. B, columnar sections showing the relationships between exposed lithostratigraphic units along part of the lower reach of Cooper Creek and Lake Palankarinna (see Fig. 4). Stratigraphic relationships of the penultimate glacial Lower Cooper Fauna and isolated *in situ* *Diprotodon* and *Sthenurus* of UCMP V5866 (lower Cooper) and V5854 (Lake Palankarinna) in the Kutjira Formation and the Malkuni Fauna last-glacial assemblage in the Katipiri Formation are shown. Calcreted sand sheets overlying these fluvial deposits also yield extinct taxa as indicated and are within the range of C14 dating.

bones amongst the suite of intra- and extraformational clasts that formed the lag at the base of the Katipiri channels. At Katipiri

Waterhole the red mudstones of the Tirari Formation are exposed and the deeply-pocketed disconformity surface is packed with rolled

selenite, gypsum-cemented rhizonodules, some of large size, flat celestite pebbles and red and green clayballs along with limonite pseudomorphs of wood and fragmentary bones. Rarer pebbles of quartz, quartzite (including silcrete) and limestone from older Tertiary terrain are also present. This suite of clasts was derived from the older terrain on the margin of the Quaternary basin, from the Tirari Formation (mudstone, celestite and selenite) and from the newly-recognized Kutjitara Formation (rhizonodules and some selenite) within the basin. The basal Katipiri Sands are fine to medium-grained with lenses of medium to coarse grains, predominantly cross-stratified, limonite-stained at the base, but finer-grained and white above. A younger suite of channel fills has been incised into the Katipiri Sands. The fills carry a larger suspended-load component. They are well-displayed at Malkuni and Katipiri waterholes and elsewhere on the lower Cooper, where cross-cutting relationships show that green and gray clays form an increasing proportion of the fill in successive channels as the suspended-load gained in importance with time. These younger channels are regarded as an aspect of the Katipiri ancestral river system which shows evolution from higher to lower discharge through time. They can be traced downstream into the delta at the mouth of the ancestral Cooper (Fig. 4) where they make up a larger part of the exposed section and yield the Madigan Gulf Fauna (Tedford, Wells & Williams, 1986), which is taxonomically similar to the Malkuni and indicates the temporal association of the deltaic and fluvial deposits. Exposures of these younger channel fills at the western end of Malkuni Waterhole contain unionid clams, but no vertebrate fossils. Here we adopt the term Katipiri Formation to include all the facies of this depositional cycle.

From the prominent red bluff near Eli Hartig's soak to Lake Kutjitara (Fig. 6B) the entrenched Cooper intersects a brightly coloured sequence of horizontally-bedded, red and green mudstones and fine sandstones interbedded with shallow channel-fills of fine to medium sand and lenses of red and green clays. Within these fluvial deposits are thin lacustrine lenses of laminated green clay and fine sand composed of reworked discoidal (displacive) gypsum crystals with charophytes and ostracods. The sandier units in this sequence are packed with gypsum-cemented rhizoconcretions of the type reworked into the basal Katipiri channels. These deposits comprise the Kutjitara Formation, named from the lake which lies adjacent to the Cooper just downstream

from the type section (Gregory's lower Cooper localities 3 and 4, Fig. 4). In this part of its reach the modern Cooper trench is incised into the top of the Miocene Etadunna Formation on which the Kutjitara Formation rests, the Tirari Formation having been removed from this area before the Quaternary rocks were laid down (Fig. 6B). At the mouth of the Cooper ancestral river the Katipiri deltaic facies rests directly on the Etadunna Formation, having stripped away the Kutjitara along its lower reach. To the S a saline lacustrine facies has been correlated with the Kutjitara (Tedford, Wells & Williams, 1986), giving evidence of an earlier lake into which subsequent deposits are incised. At the base of the Kutjitara Formation fine sands contain nodules of gypsum-cemented sand and bone fragments but no other clasts. The rare occurrence of bones in the talus of the Kutjitara outcrop suggests that this formation, particularly the basal unit, is the source of the large vertebrate remains. The concentration of bones in the bars at the locality is presumably due to the proximity of their source, a situation similar to that found upstream at the base of the Katipiri Formation outcrop. Thus Gregory's lower Cooper localities yield a fauna derived mainly from the Kutjitara Formation.

#### WARBURTON RIVER

An outstanding feature of the N side of the lower Warburton Valley is the dissected remnants of large source-bordering dunes or "Leaside mounds" (Twidale, 1972), intersected by the modern river (Figs. 5 and 6A). These transverse dunes have a pedocal at the top, although more weakly-developed than that on the sandsheets of the Cooper. These dunes rest on gypsites developed at the top of the ancestral river deposits. Internally they show gentle northeasterly dipping, large-scale cross-laminations, each set being several metres in thickness. The dune sands include discoidal gypsum grains and clay pellets. The longitudinal dunes of the Tirari Desert overlie or seem to originate from these sand piles. No C14 dates have been obtained for these deposits, but on the basis of stratigraphy they seem to be contemporaneous with the calcareated sand sheets on the Cooper. The dunes reflect continued high groundwater levels at the close of a major period of aggradation.

At Ulbarinna the floor of the Warburton exposes nodular silcrete (the "stony crossing") developed in Tertiary siltstones. The Katipiri Formation overlies the silcrete, infilling a deeply-pocketed terrain with clasts derived from the Tertiary as well as gypsum-cemented clasts

derived from the Quaternary. Locally rich accumulations of fossil vertebrate remains occur in these erosional pockets. They are also redeposited in the older sand bars adjacent to the channel where the river has scoured its floor. Downstream the entrenched modern channel lies within the larger meander belt of the ancestral river, so that the walls of the present river expose only the Katipiri Formation beneath the leeside mounds. There are few fossil vertebrate accumulations until the sector between Kalamurina and Toolapinna, where the Warburton has cut through the Katipiri to expose underlying Miocene clays and dolomites of the Etadunna Formation. Gregory's major Warburton coll. comes from this area, all labelled "Kalamurina". There are several individual sites where fossils can be obtained *in situ*, all of them near the contact with the older rocks.

From Toolapinna Waterhole to Keekalanna Soakage the western bank of the ancestral Warburton is approximated by the long escarpment supported by the Tirari Formation and its massive gypcrete caprock. Its linear nature and the absence of the Tirari Formation upstream suggests that the escarpment represents a fault-line scarp. From place to place along the Tirari escarpment cross-sections of stream channel-fills cut into the top of the Tirari Formation (Fig. 6A). These are regarded as Kutjitara Formation channels because they are truncated by the ancestral river (Katipiri) trench and do not penetrate the base of the Tirari Formation. These channels are filled with cross-bedded, limonite-stained, fine sand with green clay lenses, and they bear a weaker gypcrete caprock, more like that developed on the Katipiri. In the Warburton region the Kutjitara Formation is sparingly fossiliferous, but it does contain some taxa (Keekalanna Fauna, q.v. p. 000) that are important in establishing the nature of its fauna. Downstream from Keekalanna, at Pompapillina Waterhole, the ancestral river cut through the Tirari escarpment and again established a southwesterly course to Poonarunna and finally Lake Eyre. This sector shows brown floodplain mudstones into which are incised deep channels filled with white sand with greenish clay lenses. The whole is capped by gypcrete and overlain by leeside mounds. These poorly fossiliferous rocks are thought to be the Katipiri Formation deposited in a wide palaeovalley or deltaic system. This kind of stratigraphic sequence occurs widely in the lower Warburton and lower Kallakooah. Gregory's "Poonaranni" collections would have come from these deposits.

## PLEISTOCENE VERTEBRATES, TIRARI DESERT

In 1961 Stirton, Tedford and Miller gave annotated faunal lists for the collections made by the University of California parties along Cooper Creek and in the adjacent Tirari Desert. Two suites of stratigraphically associated taxa were labelled "faunas": the Kanunka Fauna from Lake Kanunka, north of the Cooper (since shown to be associated with the Tirari Formation of late Pliocene or possibly earliest Pleistocene age), and the Malkuni Fauna from the type section of the Katipiri Sands and closely associated sites in the ancestral Cooper deposits. In 1963, Stirton figured and described a *Protemnodon* jaw ramus from Malkuni Waterhole; Miller described Malkuni flamingos (1963), pelicans (1966) and aningas (1966). Rich (1979) reviewed the dromornithids including material from the Katipiri Formation of the Cooper and Warburton. Rich, McEvey and Walkley (1978) recorded a masked owl from Malkuni Waterhole. Rich and Van Tets (1981) reviewed the pelicans, and Rich, Van Tets and McEvey (1982) discussed falcon remains studied by de Vis. Rich *et al* (1987) reviewed the record of flamingos. Hecht (1975) reviewed *Megalanina* remains, including Lake Eyre Basin material. New faunal lists from various Cooper and Warburton sites were prepared from the UCMP collections by Williams (1980). The geochronological significance of Australian Caenozoic mammals, including those from the Lake Eyre Basin, was discussed by Woodburne *et al* (1985).

In the following annotated faunal lists we have grouped material into "faunas" from single litho-stratigraphic units at one or a few clearly-correlative localities. In this way stratigraphic association, and hence contemporaneity of taxa, are controlled as far as possible.

## KUTJITARA FORMATION

### LOWER COOPER FAUNA

Localities — Gregory's Lower Cooper localities 2, 3, and 4; correlative UCMP Cooper Creek 14 (UCMP V5866) and FUAM sites. Most material collected from the bed of Cooper. All material has a distinctive yellowish-grey, dark grey, black or grey-mottled coloration. A ramus of *Sthenurus* cf. *S. andersoni* (UCMP 56472) and diprotodontid bones were collected from Kutjitara outcrop talus or attached to concretions similar to those in the basal sands of that unit.



## PISCES

*Neoceratodus* (*N. eyerensis* and *N. gregoryi*) White (1925) came from the 'Lower Cooper'. Both type specimens are dark grey to black in colour. Teleost fin-rays and skull elements are also present; Swinton (ms.) identified catfish and perch remains among these.

## REPTILIA

*Chelidae* — Turtle shell fragments are present. Swinton (ms.) recorded no fossil turtles in the Gregory collection.

*Varanidae* — *Megalania prisca* vertebrae are well represented in the Gregory and UCMP collections.

*Crocodylidae* — Bones and teeth are common at these sites. Swinton (ms.) identified all Gregory material as *Crocodylus porosus*.

## AVES

*Dromornithidae* — Swinton (ms.) identified *Geryornis newtoni* and *Dromornis australis* from limb bone fragments and vertebrae from Lower Cooper localities 4 and 2 respectively. Rich (1979) allocated this material to "Dromornithidae gen. et. sp. indet".

*Casuariidae* — Swinton (ms.) also noted the presence of emu (referred to *Dromaius patricius* de Vis, 1888, a taxon synonymous with the living *D. novaehollandiae*, *fide* Rich & Van Tets, 1982) at localities 3 and 4. Additional material in the FUAM collection confirms this view; a smaller form (SAM P25218) is also present.

*Other birds* — de Vis (1905) described eleven taxa of aquatic birds from the "Lower Cooper" without locality number these may belong to any of the sites below "Emu Camp" (Malkuni waterhole) so are not listed here. The UCMP and FUAM collections are under study by P.V. Rich and R. Baird (Monash University). Rich *et al.* (1987) reported the presence of the extinct flamingo *Xenorhynchopsis minor* de Vis, 1905, at UCMP locality V5866. Other flamingo remains were collected by FUAM in 1980 from a nearby site. Baird (pers. comm., 1987) also reports the presence of the flamingo-like Palaeolodidae, previously known only from the Miocene (Rich & Van Tets, 1982, p. 319). Other taxa based on UCMP collections from locality V5866, and listed by Rich and Van Tets (1982, Table 3), include grebes (Podicipedidae), a darter (Anhingidae, *Anhinga novaehollandiae*), a pelican (Pelecanidae, *Pelecanus conspicillatus*), cormorants (Phalacrocoracidae, *Phalacrocorax* sp.), herons (Ardeidae) and ducks (Anatidae).

## MAMMALIA

The mammalian remains exhibit two types of preservation, either deeply stained in black,

yellowish-grey or grey, permineralized and often waterworn, or mottled grey, not permineralized and usually rather complete. The larger remains, mostly extinct forms, comprise the first type, smaller remains, usually extant taxa (including dingo), the second. The following list is based only the first type of material.

*Dasyuridae* — A jaw fragment with alveoli for M<sub>4-5</sub> (FUAM coll.) appears to represent a large *Sarcophilus*.

*Diprotodontidae* — Fragments of upper incisors, two rami and postcranial bones represent *Diprotodon* (Gregory coll.). Additional material (UCMP and FUAM coll.) indicates the presence of this important Pleistocene taxon. Smaller diprotodontids are represented by postcranial remains; a lower molar fragment (SAM P20872) is identified as a smaller diprotodontine, cf. *Nototherium*, and a fragment of an upper central incisor (also SAM P20872) represents a form near *Euryzygoma*.

*Macropodidae* — Kangaroo remains are the most abundant elements, and the Sthenurinae are particularly well represented. Small potorine and macropodine remains are usually little permineralized and lightly stained; these taxa are not considered part of the mid-Pleistocene Lower Cooper Fauna.

*Protemnodon* is represented by jaw and maxillary fragments and the distinctive metatarsals IV-V. Two taxa are present, one similar in size to *P. anak*, and a larger form similar in size to *P. brehus* or *P. roechus*.

*Troposodon* cf. *T. minor* is indicated by an isolated left M<sub>4</sub> (SAM P25175), while a smaller species, comparable to *T. bowensis*, is indicated by a narrow, elongate right lower incisor whose crown is completely encircled by enamel (SAM P25181).

*Sthenurus* is well represented by jaw and limb bone fragments (UCMP and FUAM coll.). At least two taxa are present: *S.* cf. *S. andersoni*, a right ramus with M<sub>1-4</sub> (UCMP 56472) and a larger form, *S.* cf. *S. tindalei*, (UCMP 56473), an edentulous right ramus with roots, unerupted P<sub>3</sub>; SAM P25172, fragment of a right ramus with hypolophid of M<sub>3</sub>, M<sub>4</sub>, and unerupted M<sub>5</sub>; HM S69, fragment of a right ramus with M<sub>1-3</sub>.

*Procoptodon* is represented by cranial fragments, tooth fragments and edentulous jaw fragments. A right maxillary fragment with unerupted P<sub>3</sub>, M<sub>2-3</sub> (HM S19) and edentulous jaw fragments (SAM P25184 and HM S62) represent a form close to *P. rapha*.

*Macropus* remains are remarkably few; a few postcranial fragments may represent larger macropodine kangaroos.

#### KEEKALANNA FAUNA

This name was proposed by Tedford, Wells and Williams (1986) for remains obtained from the correlated Kutjitarra Formation outcrops on the lower Warburton River between Toolapinna Waterhole and Keekalanna Soakage. The principal sites for mammalian remains are outcrops at the northern end of Toolapinna Waterhole, near Camel Swamp Yard, downstream from Keekalanna Soakage and at the latter site itself. All material was collected *in situ* or in the outcrop talus (FUAM collection).

#### REPTILIA

*Crocodylidae* — A partial skull and mandible of a large crocodilian, probably *Crocodylus porosus*, was collected *in situ* in outcrops south of Camel Swamp Yard.

#### MAMMALIA

*Diprotodontidae* — A mandible of *Nototherium* sp. was collected *in situ* west of Camel Swamp Yard. This individual is the size of *N. inermis*, *sensu* Woods, 1968. *Diprotodon* is also present in these deposits. A fragmentary ramus and a calcaneum of *D. optatum* were collected at Toolapinna.

*Thylacoleonidae* — The distal end of a fibula from Keekalanna appears to represent *Thylacoleo*.

*Macropodidae* — A fragment of a lower molar of *Troposodon* was obtained at Keekalanna. Fragmentary macropodid remains of indeterminate taxa were collected at Toolapinna.

### KATIPIRI FORMATION

#### MALKUNI FAUNA

Localities — Katipiri and Malkuni waterholes (UCMP localities, V5861, and V5382, the "Emu Camp" and "Malkuni" locality of Gregory, respectively) and the river bed between these waterholes, Cooper Creek (UCMP locality V5860). At these sites sufficient material was obtained *in situ* to identify the collection with the type "Katipiri Sand" unit. The *in situ* material is light in color, often limonite-stained (yellow and red hues) and permineralized. Smaller vertebrate material from the river bed that is mottled-grey and not permineralized is not considered part of the Pleistocene Malkuni Fauna.

#### PISCES

Lungfish dental plates are present in the UCMP collection, and teleost remains are present in all

collections from these sites. Swinton (ms.) recorded percid opercula from Emu Camp.

#### REPTILIA

*Chelidae* — Turtle remains occur at these sites.

*Varanidae* — Vertebrae of *Megalania prisca* are present in the Gregory, UCMP and FUAM collections.

*Crocodylidae* — Crocodile teeth and scutes are common at these sites. A few vertebrae were also found.

#### AVES

*Dromornithidae* and *Casuariidae* — Rich (1979) recorded fragmentary ratite limbs and vertebrae from these sites as "*Dromornithidae* gen. et sp. indet". *Genyornis* is represented in the FUAM collection. Emus also occur; *Dromaius* sp. was identified by Rich and Van Tets (1982), and further remains were found by the FUAM expedition.

*Other birds* — Miller's identifications (in Stirton, Tedford & Miller, 1961; UCMP coll.) were revised by Rich and Van Tets (1982). These latter recorded a grebe (*Podiceps* sp.), a pelican (*Pelecanus conspicillatus*, Rich & Van Tets, 1981), two species of cormorant (*Phalacrocorax* sp., including the types of *P. gregorii* de Vis, 1905, and *P. vetustus* de Vis, 1905, probably synonymous with living *P. varius* and *P. carbo* respectively, Rich & Van Tets, 1982, table 5), ducks and swans (Anatidae: including *Biziura exhumata* De Vis, 1905, now identified as the living *B. lobata* by Olson, 1977; *Archaeocynus lacustris* De Vis, 1905; *Chenopsis nanus* De Vis, 1905; and cf. *Cygnus atratus*, Rich & Van Tets, 1982), a heron (Ardeidae), an extinct flamingo (*Xenorhynchopsis tibialis* De Vis, 1905), hawks and eagles (Accipitridae: including the eagle *Uroatus*, Miller in Stirton, Tedford & Miller, 1961), and an owl (*Tyto* cf. *T. novaehollandiae*, Rich, McEvey & Walkley, 1978).

#### MAMMALIA

*Dasyuridae* — A right maxillary fragment with M<sup>3-5</sup> (UCMP 60678) of *Sarcophilus* cf. *S. lanarius*, a large Tasmanian Devil.

*Peramelidae* — A left ramus fragment of *Macrotis lagotis* with well-worn M<sub>2-4</sub> and M<sub>5</sub> alveolus (SAM P25134) is stained and permineralized similar to other remains from Katipiri Waterhole and is accepted here as a Pleistocene record of the Rabbit Bandicoot.

*Vombatidae* — A jaw fragment (FUAM) and teeth (UCMP) of the giant wombat, *Phascogaleus gigas*, were obtained.

*Diprotodontidae* — *Diprotodon optatum* remains are the most conspicuous fossils. Jaw and maxillary fragments, teeth and postcranial remains



are abundant. A smaller diprotodontine is indicated by an edentulous maxillary fragment with a relatively small, double-rooted  $P^3$  (UCMP); this may represent *Nototherium* sp. or *Diprotodon minor*. Smaller limb bone fragments could belong to those taxa or *Zygomaturus*.

*Potoroidae* — A well-preserved left ramus (UCMP 56452) with characteristic preservation represents *Bettongia* cf. *B. lesueuri*.

*Macropodidae* — A variety of larger macropodids are present, of which *Protemnodon* and sthenurines is more common than *Macropus*. Smaller taxa include *Onychogalea*.

*Protemnodon* is represented by jaw and maxillary fragments and post-cranial remains. Two size-groups are evident: the more abundant smaller form is identified as *P. anak*, an example of which was figured by Stirton (1963, fig. 8), whereas the larger is *P. brehus* or *P. roechus*.

Various sthenurine kangaroos are found, and several taxa can be identified from teeth. *Sthenurus* cf. *S. atlas* is represented by an edentulous jaw fragment with an unerupted  $P_3$  (UCMP 56470). *S. tindalei* is indicated by a left maxillary fragment with  $M^{3-4}$  (SAM 25058) and a right ramus with complete dentition (UCMP 56471) a little smaller than the type and the referred material from Lake Callabonna.

A new, large sthenurine taxon is represented by a left maxillary fragment with  $P_3$   $M_{2-5}$  (SAM P25059). This new genus, to be described elsewhere, combines features of *Sthenurus* and *Procoptodon*.

*Simosthenurus* is represented by three specimens: a right ramus with  $M_{2-5}$  (UCMP 56470), a left maxillary fragment with  $M^{3-5}$  (UCMP 60669), and a right maxillary fragment with the metaloph of  $M^4$  and unworn  $M^5$  (UCMP 60674). These specimens indicate a taxon about the size of *S. browni* or *S. occidentalis*.

*Procoptodon* cf. *P. rapa* is represented by a right ramus with unerupted  $P_3$ ,  $M_{1-2}$  and unerupted  $M_{3-4}$  (SAM P11543), which was part of the small collection (presented to SAM in 1900) made by J. Hillier (Gregory, 1906, pp. 59, 77 and 80) at "Cuttipirra" waterhole, and by an unworn  $M_3$  (UCMP 60670). *Procoptodon* cf. *P. goliath* is indicated by an edentulous left maxillary fragment (UCMP 56454), a broken lower molar (UCMP 60672), and among the larger sthenurine limb bones.

*Macropus* cf. *M. titan* is present in all collections from the area, but it is not common. Smaller macropodine remains with characteristic staining and permineralization are also present. Stirton,

Tedford and Miller (1961) referred parts of two rami to "?*Wallabia*" (UCMP 56443 and 56447). These apparently represent the same taxon as SAM P25069, a fragment of a left ramus with  $M_{2-3}$  and unerupted  $M_4$ , namely *Macropus* (*Notamacropus*) *agilis siva*. From "Emu Camp" there is a fragment of a right ramus with complete cheek-tooth dentition (Gregory coll., HM S46) that corresponds in size and morphology with "*Macropus*" *rama* — previously known only from the eastern Darling Downs. A fragment of a right ramus with  $P_3$ ,  $M_{2-5}$  (SAM P25071) appears to represent the tiny Nail-Tail Wallaby, *Onychogalea lunata*.

We have not been able to relocate the 'part of a right mandible of a medium-sized macropodid, with the protolophid of  $M/4$ ,  $M/3$  complete and part of the hypolophid of  $M/2$ ', referred by Stirton, Tedford and Miller (1961, p. 49) to "?subfamily" of macropodids. The description given suggests *Troposodon minor*, a taxon not represented in Malkuni faunal collections.

*Phalangeridae* — A right ramus with incisor and complete cheek tooth dentition (UCMP 56451) represents *Trichosurus* cf. *T. vulpecula*.

#### KALAMURINA FAUNA

Localities — Three sites N and W of old Kalamurina Station homestead (corresponds with "Kalamurina" locality of Gregory, 1906): V5569 ("Marcus Locality"), V5775 ("Green Bluff Locality") and V5776 ("Lookout Locality"). Material was collected *in situ* or on the outcrop talus from strata correlated with the Katipiri Formation. Limited screen-washing in 1980 yielded *in situ* small vertebrate remains. Field parties after 1980 made collections upstream, at the silcrete bars at Toopawarinna (vicinity of New Kalamurina Station homestead, UCMP V72058) and Ulabbarrinna (UCMP V5776, Cassidy Locality), and from intermediate sites (as had Brown and Gregory). The fauna from these latter sites is derived from correlative strata and seems equivalent to that from the Kalamurina sites.

#### PISCES

White (1925) referred Kalamurina material to the lungfishes *Neoceratodus eyrensis* and *N. gregoryi*. Catfish spines and percoid opercula are among the abundant teleost fish remains from Kalamurina (Swinton, ms.).

#### REPTILIA

*Chelidae* — Fragmentary turtle remains are present.

*Varanidae* — *Megalania prisca* vertebrae are present and a smaller varanid is also indicated.

*Pythonidae* — Swinton (ms.) reported a vertebra of "*Python* sp." (HM B809), that "agreed very

closely with the vertebrae of the modern *P. spilotes*, but is twice the size of those of that species". This specimen should be compared with the extinct giant python *Wonambi* Smith, 1976.

*Crocodylidae* — teeth, scutes and postcranial elements are reasonably common. Material includes the partial skull (UCMP 47936) of a large *Crocodylus porosus* (R. Molnar, pers. comm.).

#### AVES

*Dromornithidae* and *Casuariidae* — Rich and Van Tets (1982, table 3) record both unidentified dromornithids and the emu *Dromaius novaehollandiae* from the Kalamurina sites.

*Other birds* — de Vis (1905) identified a number of smaller bird taxa (all described as new) from "Kalamurina". Rich and Van Tets (1982, table 5) allocated these as follows: duck or swan-like forms, Anatidae, *Anas gracilipes* de Vis, 1905 (synonymous with *A. castanea*, fide Olson, 1977), and *Archaeocynus lacustris* de Vis, 1905; cormorants, *Phalacrocorax gregorii* de Vis, 1905 (probably *P. carbo*); *P. vetustus* de Vis, 1905, (the assigned material probably *Leucocarbo fuscescens* and *P. carbo*) and possibly a vulture, *Taphaetus lacertosus* de Vis, 1905 (Accipitridae, questionably Gypaetinae). In addition Rich and Van Tets (1982, Table 3) recorded darters (Anhingidae, *Anhinga* sp.), pelicans (Pelecanidae, *Pelecanus conspicillatus*), herons (Ardeidae) and unidentified songbirds.

#### MARSUPIALIA

*Dasyuridae* — A nearly complete right ramus of *Sarcophilus* cf. *S. lanarius* (UCMP 46193, Marcus Locality) was mentioned by Stirton (1957, p. 131) from 'the Pliocene at Kalamurina'; measurements were also given (ibid., table, p. 132).

*Vombatidae* — Remains of *Phascolonius gigas* include cheek teeth and a right ramus with P<sub>3</sub> M<sub>2-4</sub> (UCMP 56832, Lookout Locality).

*Diprotodontidae* — *Diprotodon* remains are the most conspicuous fossils along the Warburton. A partial skull, jaw, and limb fragments have been obtained *in situ*. Most represent the large morph *D. optatum*. Fragmentary remains indicate the rarer occurrence of a small *Zygomaturus*, (UCMP 56796, left M<sub>3</sub>; UCMP 56834, left I<sup>3</sup>). Another small diprotodontine, possibly *Nototherium*, is represented by a maxillary fragment with roots of P<sup>3</sup> and M<sup>2</sup> and a lower incisor from Kalamurina (presented by E.A. King to SAM, 1906).

*Thylacoleonidae* — E.A. King also presented a left P<sup>3</sup> of *Thylacoleo carnifex* (Kalamurina, SAM P103). An I<sup>3</sup> (Marcus locality, UCMP 56834) and medial phalanx of the manus are also referable to the marsupial lion.

*Phascolarctidae* — A fragment of a left ramus of a large koala, *Phascolarctos* sp., with P<sub>3</sub> M<sub>2-4</sub> (FUAM 204) was obtained at the Lookout Locality.

*Macropodidae* — Most of the mandibular and skull fragments pertain to extinct genera. As on the Cooper, species of *Macropus* are relatively rare at these Warburton sites.

*Protemnodon* is represented by *P.* cf. *P. anak*, (left maxillary fragment with broken M<sup>2-3</sup> and complete M<sup>4-5</sup>; UCMP 56745), and a larger form by limb bone fragments.

Sthenurine kangaroos are represented by *Sthenurus*, *Simosthenurus* and *Procoptodon*. *Tropododon* may also be present if a small, slender and elongate metatarsal IV (SAM P20978) and a correspondingly slender and elongate proximal phalanx of this metatarsal with sthenurine ligament scars, can be referred to this taxon.

*Sthenurus andersoni* is represented by a left P<sup>3</sup> (UCMP 60867) and a number of rami (FUAM), and *S. tindalei* by jaw fragments (UCMP 56808, 56809) that show most of the lower dentition. A large *Sthenurus*, comparable to the undescribed large species from Lake Callabonna, is indicated by a unworn right M<sub>4</sub> (King coll., SAM).

*Simosthenurus* is also present and represented by two forms, *S.* cf. *S. orientalis* (left M<sup>4-5</sup>; UCMP 56901), and *S.* cf. *S. pales* (left ramus fragment with unerupted M<sub>4-5</sub>; UCMP 56807).

*Procoptodon* is represented by juvenile jaw fragments of *P. rapha* (UCMP 56831) and *P.* cf. *P. goliath* (UCMP 56810) and two adult rami (SAM P20917 and P20958). Measurements of the cheek teeth of these specimens agree better with the eastern Darling Downs sample of *P. goliath* than with the larger individuals from Lake Menindee.

An euro, *Macropus (Osphranter)* sp., is indicated by upper teeth (UCMP 56835) and by a right maxillary fragment with broken M<sup>2</sup> and complete M<sup>3-4</sup> (UCMP 60866). *Macropus* cf. *M. titan*, a left M<sub>4-5</sub> (unerupted), is present (King coll., SAM) and a smaller macropodine of wallaby-size is represented by a jaw fragment with well-worn teeth (UCMP). A fragment of left ramus with M<sub>2-3</sub> (SAM P20927) appears to represent *Lagorchestes*. Limb bone fragments indicate the presence of large and small macropodines, showing that their diversity is under-represented by dental remains.

#### EUTHERIA

*Muridae* — A few rodent jaw fragments and teeth were obtained by screen-washing sand lenses at Lookout Locality. The more useful material includes at least two taxa of conilurine mice, one near *Conilurus* (SAM P20944), the other a smaller

form (SAM P20930) of *Pseudomys* or *Notomys* size.

## CONCLUSIONS

*Geological History* — The oldest recognized Quaternary deposits, the Kutjitarra Formation, represent a broad alluvial apron which descended from bordering Tertiary uplifts on the eastern side of the Lake Eyre basin towards a depositional centre now buried beneath younger deposits NW of Lake Eyre North. These interior basin deposits were laid down at a time of higher groundwater level than at present, one that supported lacustrine bodies lying SE of, and possibly beneath, the present Lake Eyre salina and extending northward to the depocentre. These waters were saline for lengthy intervals, indicating a negative water balance for the basin, especially for the waning phases of deposition. The postulated aeolian facies corresponding to more arid environments at the close of Kutjitarra deposition have not been found, but the upper part of the unit was indurated with groundwater gypsum to form a regional gypcrete surface.

A significant change in basin geometry took place during the hiatus between deposition of the Kutjitarra and Katipiri Formations. This was initiated by tectonic subsidence of the southern part of Lake Eyre, the consequent entrenchment and southward shift of drainage, and the integration of the Lake Eyre Basin with the catchments for the Diamantina and Cooper systems in Queensland. Aggradation in this fluvial system probably began on maintenance of Lake Eyre as a perennial lake. The abundance of freshwater vertebrates in the Katipiri Formation indicates a low salinity environment at least for protracted periods within the trunk streams, if not in the lake itself. The close of Katipiri deposition was marked by waning discharge (shift from bed to suspended loads), a shrinking lake bordered by recessional strandline dunes, and slowing of deposition under an increasingly negative water balance with the formation of a gypsum-indurated horizon at the top of the lowering regional water table. Aeolian deposits overlie this gypcrete. Sandsheets indurated by calcrete occur in the Cooper area and large transverse dunes or leeside mounds adjacent to the valley of the Warburton are also capped by calcrete. These evidences of regional aridity occur at the limit of conventional radiocarbon dating.

Most of the Quaternary depositional record occurs beyond 40 Ka with both lithostratigraphic

units recording a shift from positive to negative water budgets in the Lake Eyre Basin, despite differences in depositional geometry. This supports the idea that these units are related to the same extrabasinal control (i.e. climate) and, further, that the climatic cycling is associated with the glacial cycles from evidence in surrounding regions (Bowler, 1976, 1978). Accordingly the Katipiri Formation is regarded as last glacial, the fluvial sedimentation taking place in the early phases, the aeolian facies forming before 40 Ka, first as transverse dunes associated with lake recession, and in riverine tracts, and, finally, at the peak of aridity, as the longitudinal dune system representing the glacial maximum. The Kutjitarra is taken to represent the previous glacial cycle, the penultimate, about 200 Ka, and, despite the absence of an aeolian facies, the saline lake facies are evidence of arid climates. There is a considerable hiatus between the Kutjitarra Formation and the underlying terrain, the youngest deposits of which are the Tirari Formation. The Tirari is predominantly reversely magnetized, and represents the Matuyama Chron (period of magnetic pole reversal) whose latest limit is about 700 Ka. The interval between 700 and 200 Ka remains unrepresented by deposits in the Lake Eyre Basin. The initiation of local sedimentation (Kutjitarra Formation) in mid-Pleistocene time must be traced to tectonic events, perhaps major subsidence in the northern part of the Lake Eyre Basin. Tectonic control is implicated in the subsequent history of the basin.

*Vertebrate History* — Any assessment of Pleistocene vertebrate history in the Lake Eyre Basin must take into account any bias in the fossil record, which is drawn almost entirely from fluvial facies.

Aquatic lower vertebrates and water birds dominate the fauna; terrestrial mammals are relatively rare. In addition, collections from the two lithostratigraphic units are unequal in size: those from the Kutjitarra Formation are about half as big as those from the younger Katipiri Formation.

Pleistocene faunas in the Tirari Desert were entombed during vigorous fluvial and high water-table regimes. These episodes, we believe, are correlative with lacustrine phases of the earlier half of glacial cycles that, at minimum, represent the last two glacials. In Australian terms, these would correspond to paleoclimatic phases IV and VI at Lake George, New South Wales, the longest continuous Pleistocene record presently available in Australia (Singh, Opdyke & Bowler, 1981).

Median ages for these phases are estimated at about 70 Ka and 160 Ka respectively. Following this reasoning the Quaternary depositional record preserved in the Tirari Desert would cover parts of the last third of the Pleistocene.

The rich fauna of aquatic vertebrates includes many forms that presently reside in the Lake Eyre region whenever permanent soakage-fed deep billabongs prevail. Similarly, many of the large raptorial birds still occupy the region. Most of the de Vis' (1905) bird taxa were found to represent living forms when adequate comparative osteological collections were available (Rich & Van Tets, 1982). The ephemeral rivers, saline groundwater and consequent reduction of food supply of the present interglacial, can account for the extinction of lungfish and crocodiles. More enigmatic, given their present adaptation to saline environments, is the loss of the diverse flamingo population that was once a prominent element in the aquatic bird fauna. Rich *et al* (1987) record two extinct genera and the living *Phoenicopertus ruber* in these Pleistocene deposits.

Terrestrial reptiles, the giant goanna and python, were the largest carnivores in evidence in these deposits. These were many times larger than contemporary mammalian carnivores, the Tasmanian Devil and Marsupial Lion, which must be counted among the prey of these reptiles. The record supports the conclusion that the lower vertebrate component of the later Pleistocene biota of the Lake Eyre Basin persisted from the Kutjirara to Katipiri formations. Although much of this fauna persists in the area today, there was notable extinction of some characteristic elements in post-Katipiri time.

Much the same conclusions apply to the larger marsupials except that this fauna was more markedly reduced before post-glacial time. Conspecific or closely related taxa in the following genera are common to both the faunas of the Kutjirara and Katipiri formations: *Sarcophilus*, *Thylacoleo*, *Diprotodon*, *Protemnodon*, *Sthenurus*, and *Procoptodon*. Given the unequal size of collections from these formations, absences and differences in abundance are difficult to interpret, but *Diprotodon* is not so conspicuous in the Kutjirara faunas. Other diprotodontines (especially *Nototherium*) are more in evidence in the Kutjirara Formation, and the macropodid fauna includes *Troposodon* but not *Simosthenurus*. On the other hand the faunas of the Katipiri Formation have abundant large *Diprotodon optatum* whereas smaller diprotodontids, including *Zygomaturus*, are rare.

Giant wombats, *Phascogale*, are well-represented, and at least two species of *Simosthenurus* are present, as is *Sthenurus atax*. Further collecting may alter the significance of these differences. For the moment we suspect that the greater diversity of the Katipiri Formation faunas must be partly due to the greater size of collections available. We cannot, on present evidence, detect significant faunal change, at least on the generic level, in the larger marsupials during the later third of the Pleistocene in the Lake Eyre Basin.

Much the same conclusion is reached from examination of the later Pleistocene sequences in two nearby basins SW of Lake Eyre. In the Pleistocene Lake Frome Basin, South Australia, the Millyera, Coomb Spring and Euranilla Formations, in ascending order, record Pleistocene climatic cycles (Callen, 1984) correlative with those from the Lake Eyre Basin. At Lake Callabonna the lacustrine facies of the Millyera Formation contains entrapped large-bodied terrestrial vertebrates (Lake Callabonna Fauna, older references in Williams, 1980). These deposits are correlative with the Kutjirara Formation, and the similar fauna contains *Diprotodon optatum*, *Protemnodon brehus* or *P. roechus*, *Sthenurus andersoni*, and *S. tindalei*. In addition, *Phascogale gigas*, and a new large *Sthenurus* species are shared with the younger Katipiri faunas. The fluvial Eurinilla Formation overlies the Millyera and Coomb Spring units and has a fragmentary assemblage (Billeroo Creek Fauna) closely comparable in occurrence, stratigraphic position and taxonomic composition with the Katipiri Formation assemblages. Williams (1980) listed in addition to taxa of the older Millyera Formation, *Thylacoleo carnifex*, *Macropus cf. M. ferragus*, *M. (Osphranter) sp.*, the large "*Sthenurus*" sp. nov. and *Procoptodon goliath* in the Billeroo Creek Fauna. Again the evidence indicates little taxonomic change in the large marsupial assemblage over the 700-100 Ka span estimated from local geochronological evidence (Callen, 1984).

At Lake Victoria in the central Murray Basin, southwestern New South Wales, Gill (1973) defined two later Pleistocene lithostratigraphic units lying above the late Pliocene-early Pleistocene Blanchetown Clay and its facies, the Bungunnia Limestone. Subsequent paleomagnetic work (An *et al.*, 1986) has established that the top of the Blanchetown Clay includes the Matuyama-Brunhes boundary, so that the overlying units represent a later part of the Brunhes



Chron. The Rufus Formation fluvial deposits form the more superficial fill of the Murray paleovalley following incision of the Blanchetown Clay and draining of early Pleistocene Lake Bungunnia. The Rufus Formation contains the Frenchman's Creek Fauna of Marshall (1973) which includes the same large marsupial taxa as obtained from the Kutjira and Katipiri formations in the Lake Eyre Basin, namely *Sarcophilus*, *Phascolonus*, *Procoptodon gollah* and *Macropus titan*, along with smaller taxa still extant (*Lasiornis*, *Bettongia*, *Onychogalea*) and *M. agilis siva*. The lunette of Lake Victoria overlies the Rufus Formation and these aeolian deposits, termed the Lake Victoria Sands by Gill (1973), were divided into two members: the Nulla Nulla Sands of late Pleistocene age (greater than 15 Ka) and the overlying Talgarray sand of Holocene age. These deposits produced the "Lake Victoria Local Fauna" of Marshall (1973), a composite assemblage of Late Pleistocene and Holocene age, considered together because of difficulties of determining provenance. The large marsupial fauna is very diverse and includes the following taxa in common with the Lake Eyre and Lake Frome basins: *Sarcophilus laniarius*, *Thylacoleo carnifex*, *Phascolonus gigas*, *Sthenurus andersoni*, *S. atlas*, *S. tindalei*, *Procoptodon gollah*, *Protemnodon anak*, *P. brehmsi*, *Macropus titan*, and *Diprotodon optatum*. The Frenchman's Creek Fauna is reconstructed from a smaller collection than the Lake Victoria Fauna, but as we have demonstrated in the more interior basins, there is a significant similarity of the large mammal faunas. The evidence from the Murray Basin does not permit closer estimate of the age range of these assemblages than from less than 700 Ka to greater than 15 Ka, which includes the span interpreted for the Pleistocene sequences in the Lake Eyre and Lake Frome basins.

Elsewhere in Australia faunas now thought to be later Pleistocene, but older than 100 Ka, e.g. the Victoria Cave assemblage, southeastern South Australia (Wells, Moriarty & Williams, 1984) and the Wellington Caves assemblage, New South Wales (Dawson, 1985), although much more diverse taxonomically than the fluvial sites discussed here, contain the same genera. Major faunal changes in later Pleistocene time seem to be associated with the latest part of the last glacial, probably coincident with the glacial maximum (see Horton, 1984, for summary).

Only the recently-discovered Nelson Bay Local Fauna of coastal southwestern Victoria has been accurately dated as early Pleistocene. The local

magnetostratigraphy for the site, coupled with constraints from foraminiferal biochronology and radioisotopic dating of the underlying basalts, indicate a span of 1700-700 Ka within the late Matuyama Chron for the Nelson Bay Local Fauna (MacFadden *et al.*, 1987). This local fauna contains *Diprotodon* sp., *Zygomaturus trilobus*, *Palorchestes parvus* and *Protemnodon* sp. shared with later Pleistocene assemblages. Unique taxa, such as the macropodid *Baringa* and a giant pseudocheirine, suggest that Early Pleistocene faunas, when they are better known, may show important differences at the generic and specific level from those of the later Pleistocene.

Important summaries of Quaternary large marsupial distribution have been compiled by Hope (1982) and Horton (1984) whilst examining the question of late Pleistocene extinction. The new data presented here indicate that during later Pleistocene glacial phases most larger marsupial genera had species ranging into central Australia. An analysis of genera shows little taxonomic difference between the centre and contemporary faunas of the southeastern periphery, at least during parts of late Quaternary time. Habitat diversity during these times was such that "disharmonious" (*sensu* Lundelius, 1983) associations of still-living taxa occur in these last glacial deposits in central Australia comparable to those of the periphery. In the Malkin and equivalent Kalamurina faunas, representatives of the living *Phascolarctos* sp., and *Macropus agilis*, now restricted to eastern and northern woodlands and savannas of Australia (Fig. 7) coexisted with the southwestern arid land Nail-Tail Wallaby (*Onychogalea lunata*) and the Tasmanian Devil. Other arid-adapted species, such as *Bettongia lesueur*, *Macrotis lagotis* and *Trichosurus vulpecula*, present in these faunas still inhabited the Lake Eyre Basin at the time of European occupation. The implications from such associations for the interpretation of the environment during the early phases of the last glacial cycle are summarized by Lundelius (1983). His study of fossil vertebrates from similar-age Pleistocene sites scattered around the periphery of the continent revealed many "disharmonious" pairs of taxa, implying a more equable climate than at present. The extension of the data into the Lake Eyre Basin in the present arid core of the continent suggests that much lower climatic gradients existed across Australia during those times than during glacial maxima or interglacials. Penultimate glacial events recorded in the Kutjira Formation similarly include a shift from freshwater lacustrine

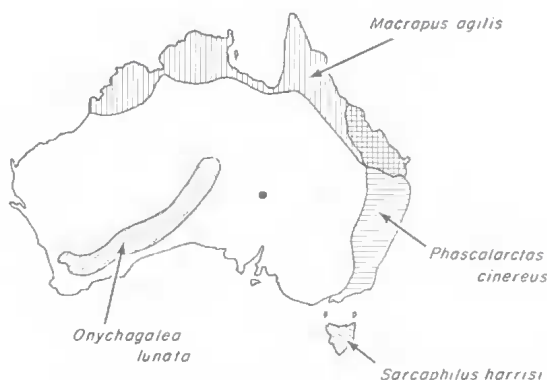


FIG. 7. Geographic ranges of four living species that occur sympatrically in the last-glacial Malkuni Fauna of central Australia (black dot) illustrating the concept of "disharmonious" glacial faunas of Lundelius (1983).

to saline and thus arid conditions, but without evidence of extensive dune building. The Lower Cooper and equivalent Keekalana faunas are like their later counterparts, and thus indicate survival of much of the large vertebrate faunas through the postulated shift from broadly equable to zonal climate in passage from glacial to interglacial times. Unfortunately the older collections are not large enough to detect disharmonious taxa, but the persistence of the large mammals suggests no radical depletion of niches at the close of the penultimate glacial. This is in contrast to the striking evidence Lundelius (1983) presented for ecological reorganization toward the end of the last glacial. Either there was a quantitative difference in environmental impact of the last two glacial cycles (as suggested by the absence of penultimate glacial dune fields) or other factors, including human predation, are involved in terminal Pleistocene extinction.

#### ACKNOWLEDGEMENTS

We wish to acknowledge our indebtedness to our field companions of the 1980 expedition: Drs John Bye and David Catcheside, Flinders University, Mr Paul Lawson, Adelaide and the late Dr Dominic Williams (a tribute to whom appears in Wells and Callen, 1986) and the 1983 expedition: Mr Ed Bailey and Ms Sandi Tartowski, Flinders University, Dr Steven Barghoorn, American Museum of Natural History, Mr Paul Lawson, Adelaide. The success of our field work is due in great measure to their hard work and companionship. In 1980 Dr Roly Byron-Scott,

Flinders University, piloted a light aircraft on our first aerial reconnaissance and in 1983 Mr Peter Dunn provided further aerial reconnaissance and support for ground visits to remote sites on the lower Kallakoopah. The Dunn family of New Kalamurina Station, Jim and Joan Dunn (1980) and their children, Peter and Jenny Dunn (1983), offered traditional bush hospitality and aided us in many ways. Brian and Cath Oldfield (Etadunna) and Kevin Oldfield (Clayton) also made us welcome in work on their stations.

#### LITERATURE CITED

- AN, Z.-S., BOWLER, J.M., OPDYKE, N.D., MACUMBER, P.G., AND FIRMAN, J.R. 1986. Paleomagnetic stratigraphy of Lake Bungunnia: Plio-Pleistocene precursor of aridity in the Murrumbidgee Basin, Southeastern Australia. *Palaeogeography, Palaeoclimatology, Palaeoecology* 54: 219-39.
- ARCHER, M. 1978. The nature of the molar-premolar boundary in marsupials and a reinterpretation of the homology of marsupial cheek teeth. *Memoirs of the Queensland Museum* 18: 157-64.
- BOWLER, J.M. 1976. Aridity in Australia: age, origins and expression in aeolian landforms and sediments. *Earth-Science Reviews* 12: 279-310.
1978. Glacial age aeolian events at high and low latitudes: a southern Hemisphere perspective. p. 149-71 In, E.M. Van Zinderen Bakker (Ed.), 'Antarctic glacial history and world palaeoenvironments'. (A.A. Balkema: Rotterdam).
- BROWN, H.Y.L. 1892. Government geologists report on country in the neighbourhood of Lake Eyre. *South Australian Geological Survey*, 1892, 5pp.
- CALLEN, R.A. 1984. Quaternary climatic cycles, Lake Millyera region, Southern Strzelecki Desert. *Transactions of the Royal Society of South Australia* 108: 163-73.
- DAWSON, L. 1985. Marsupial fossils from Wellington Caves, New South Wales; the historic and scientific significance of the collections in the Australian Museum, Sydney. *Records of the Australian Museum* 37: 55-69.
- DEBNEY, G.L. 1881a. Notes on the physical and geological features about Lake Eyre. *Transactions of the Royal Society of South Australia* 4: 145-6.
- 1881b. Sections of strata traversed in boring for water in the country between Cooper Creek and Warburton River. *Transactions of the Royal Society of South Australia* 4: 147-8.
- DE VIS, C.W. 1905. A contribution to the knowledge of the extinct arid fauna of Australia. *Annals of the Queensland Museum* 6: 3-25.
- ETHERIDGE, R., JR. 1894. Official contributions to the palaeontology of South Australia. No. 6-Vertebrate remains from the Warburton or Diamantina River. *Annual Report of the Government Geologist, South Australia* 1894, p. 19-22.



- FLANNERY, T.F. AND HANN, L. 1984. A new macropodine genus and species (*Marsupialia: Macropodidae*) from the early Pleistocene of Southwestern Victoria. *Australian Mammalogy* 7: 193-204.
- GAFFNEY, E.S. 1981. A review of the fossil turtles of Australia. *American Museum Novitates* 2720: 1-38.
- GILL, E.D. 1973. Geology and geomorphology of the Murray River region between Mildura and Renmark, Australia. *Memoirs of the National Museum of Victoria* 34: 1-97.
- GREGORY, J.W. 1906. 'The dead heart of Australia'. (John Murray: London).
- HECHT, M.K. 1975. The morphology and relationships of the largest known terrestrial lizard, *Megalania prisca* Owen, from the Pleistocene of Australia. *Proceedings of the Royal Society of Victoria* 87: 239-52.
- HOPE, J. 1982. Late Cainozoic vertebrate faunas and the development of aridity in Australia. p. 85-100. In Barker, W.R. and Greenslade, P.J.M. (Eds), 'Evolution of the Flora and Fauna of Arid Australia'. (Peacock Publications, Frewville, South Australia).
- HORTON, D.R. 1984. Red Kangaroos: last of the Australian megafauna. p. 639-80. In Martin, P.S. and Klein, R.G. (Eds), 'Quaternary Extinctions'. (University of Arizona Press: Tucson).
- KRIEG, G.W. AND CALLEN, R.A. 1980. Geological observations in the playa region of the Simpson Desert, South Australia. *Department of Mines and Energy, South Australia, Geological Survey Report*, 80/68, 24p.
- LUNDELIUS, E.L., JR. 1983. Climatic implications of late Pleistocene and Holocene faunal associations in Australia. *Alcheringa* 7: 125-49.
- MACFADDEN, B.J., WHITELAW, M.J., MCFADDEN, P. AND RICH, T.H.V. 1987. Magnetic polarity stratigraphy of the Pleistocene section at Portland (Victoria), Australia. *Quaternary Research* 28(3): 364-73.
- MARSHALL, L.G. 1973. Fossil vertebrate faunas from the Lake Victoria region, S.W. New South Wales, Australia. *Memoirs of the National Museum of Victoria* 34: 151-72.
- MILLER, A.H. 1963. The fossil flamingos of Australia. *Condor* 65: 289-99.
- 1966a. The fossil pelicans of Australia. *Memoirs of the Queensland Museum* 14: 181-90.
- 1966b. An evaluation of the fossil anhingas of Australia. *Condor* 68: 315-20.
- OLSON, S.L. 1977. The identity of the fossil ducks described from Australia by C.W. de Vis. *Emu* 77: 127-31.
- REUTHER, J.G. 1981. The Dieri (translated from Reuther ms 1901 by P.A. Scherer) *Australian Institute of Aboriginal Studies, Canberra, Microfiche No. 2*.
- RICH, P.V. 1979. The Dromornithidae. *Bulletin of the Bureau of Mineral Resources, Geology and Geophysics, Australia* 184: 1-196.
- MCEVERY, A.R. AND WALKLEY, R. 1978. A probable masked owl, *Tyto novaehollandiae*, from Pleistocene deposits of Cooper Creek, South Australia. *Emu* 78: 88-90.
- AND VAN TETS, G.F. 1981. The fossil pelicans of Australia. *Records of the South Australian Museum* 18: 235-64.
- AND VAN TETS, G.F. 1982. Fossil birds of Australia and New Guinea: their biogeographic, phylogenetic and biostratigraphic input. p. 236-84. In Rich, P.V. and Thompson, E.M. (Eds), 'The Fossil Vertebrate Record of Australasia'. (Monash University Offset Printing Unit: Clayton, Victoria).
- VAN TETS, G.F. AND MCEVERY, A.R. 1982. Pleistocene records of *Falco berigora* from Australia and the identity of *Asturastetus furcillatus* De Vis (Aves: Falconidae). *Memoirs of the Queensland Museum* 20: 687-93.
- VAN TETS, G.F., RICH, T.H.V. AND MCEVERY, A.R. 1987. The Pliocene and Quaternary flamingos of Australia. *Memoirs of the Queensland Museum* 25(1): 207-25.
- SING, G., OPDYKE, N.D. AND BOWLER, J.M. 1981. Late Cainozoic stratigraphic, paleomagnetic chronology and vegetational history from Lake George, N.S.W. *Journal of the Geological Society of Australia* 28: 435-52.
- STIRTON, R.A. 1954. Digging Down Under. *Pacific Discovery* 7: 2-13.
1957. Tertiary marsupials from Victoria, Australia. *Memoirs of the National Museum of Victoria* 2: 121-34.
1963. A review of the macropodid genus *Protemnodon*. *University of California, Publications in Geological Sciences* 44: 97-162.
- TEDFORD, R.H. AND MILLER, A.H. 1961. Cenozoic stratigraphy and vertebrate paleontology of the Tirari Desert, South Australia. *Records of the South Australian Museum* 14: 19-61.
- SWINTON, W.E., ms (c. 1924). Description of the vertebrate remains collected by Professor J.W. Gregory, D. Sc., PRS, in the Lake Eyre district of South Australia. Hunterian Museum, University of Glasgow, 33p.
- TATE, R. 1886. Post-Miocene climates in South Australia. *Transactions, Proceedings and Reports of the Royal Society of South Australia* 8(for 1884-5): 49-59.
- TEDFORD, R.H. 1985. The Stirton years 1953-1966, a search for Tertiary mammals in Australia. p. 38-57. In Rich, P.V. and Van Tets, G.F. (Eds), 'Kadimakara, extinct vertebrates of Australia'. (Pioneer Design Studio: Lilydale, Victoria).
- WELLS, R.T. AND WILLIAMS, D.L.G. 1986. Late Cainozoic sediments and fossil vertebrates. p. 42-72. In Wells, R.T. and Callen, R.A. (Eds), 'The Lake Eyre Basin-Cainozoic sediments, fossil vertebrates and plants, landforms, silcretes and climatic implications'. *Australasian Sedimentologists Group Field Guide Series, No. 4*. (Geological Society of Australia: Sydney).
- TWIDALE, C.R. 1972. Evolution of sand dunes in the Simpson Desert, central Australia. *Institute of British Geographers, Transactions*, 56: 77-109.
- WELLS, R.T. AND CALLEN, R.A. (Eds). 1986. 'The Lake Eyre Basin-Cainozoic sediments, fossil vertebrates and plants, landforms, silcretes and climatic

- implications'. *Australasian Sedimentologists Group Field Guide Series No. 4*. (Geological Society of Australia: Sydney) 176 pp.
- MORIARTY, K. AND WILLIAMS, D.L.G. 1984. The fossil vertebrate deposit of Victoria Fossil Cave Naracoorte: an introduction to the geology and fauna. *Australian Zoologist* **21**: 30-33.
- WHITE, E.I. 1925. Two new fossil species of *Epiceratodus* from South Australia. *Annals and Magazine of Natural History* **16**: 139-46.
- WILLIAMS, D.L.G. 1980. Catalogue of Pleistocene vertebrate fossils and sites in South Australia. *Transactions of the Royal Society of South Australia* **104**: 101-15.
- WOODBURNE, M.O., TEDFORD, R.H., ARCHER, M., TURNBULL, W.D., PLANE, M.D. AND LUNDELIUS, E.L. 1985. Biochronology of the continental mammal record of Australia and New Guinea. *Special Publications, South Australian Department of Mines and Energy* **5**: 347-63.